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EFFECTS OF GROWTH REGULATORS ON THE NUMBER AND LENGTH OF INTERNODES IN SPROUTS FORMED ON TRIMMED SILVER MAPLE

Report No 87-148-K

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ABSTRACT

The stems of trimmed silver maple seedlings, grown in the greenhouse, were injected with the growth regulators MBR 18337, PP 333 and EL-500. Stem injection resulted in an inhibition of sprout growth. Similar results were obtained when trimmed silver maple trees grown in the field were trunk injected with PP 333 and EL-500. In both seedlings and trees the reduction in sprout growth observed after application of PP 333 and EL-500 was the result of an inhibition of internode elongation and a reduction in the number of internodes per sprout. Application of MBR 18337 to seedlings resulted in an inhibition of internode elongation but a reduction in the number of internodes per sprout was not observed (at the application rates used).

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EXECUTIVE SUMMARY

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The trimming of problem trees under distribution lines on city streets and in rural areas is a major problem and expense for electrical utilities. Such operations are routinely performed at intervals of one to eight years depending on the growth rate of the individual species and the amount of line clearance required.

In recent years, a group of new growth regulators has been introduced which is effective in controlling the growth of trees without producing noticeable injury symptoms. Members of this group, MBR 18337, PP 333 and EL-500, have been applied to trees by trunk injection, a method which offers some advantages over other application methods such as foliar spray and soil injection. Drift is avoided, there is greater control over the rate applied, and the exposure of the applicator to the chemical is limited. The effects of PP 333 on woody and non-woody plant growth have been studied extensively. Various effects have been reported, including an inhibition of internode elongation, an increased tolerance to water stress, a reduction in the number of sprouts formed and in the size of leaves formed, an increase in chlorophyll content, an increased cold tolerance in crops, and an increased tolerance to SO_2.

In the present study the effects of trunk injection of MBR 18337, PP 333 and EL-500 on sprout growth in silver maple seedlings grown in the greenhouse and of PP 333 and EL-500 on sprout growth in silver maple trees grown in the field were investigated. In both seedlings and trees there were significant reductions in sprout growth. The reductions in growth observed following application of PP 333 and EL-500 were the result of both an inhibition of internode elongation and a

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duction in the number of internodes formed per sprout. Since
rout length is a function of both the length of the individual
ternodes in the sprout and the number of those internodes,
en growth regulators such as PP 333, EL-500 are more effective
controlling tree growth when they influence both parameters
ther than just one. MBR 18337 was found to inhibit internode
ongation in silver maple seedlings but had no effect on
ternode number (at the application rates used).

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To Dr. D. Mills
Director of Research

EFFECTS OF GROWTH REGULATORS ON THE NUMBER AND LENGTH OF INTERNODES IN SPROUTS FORMED ON TRIMMED SILVER MAPLE

1.0 INTRODUCTION

The trimming of trees under distribution lines on city streets and in rural areas is a major problem and expense for electrical utilities. Such operations are routinely performed at intervals of one to eight years depending on the individual species growth rate and the amount of line clearance required (Gardner, 1971; EPRI, 1979, 1982).

Much effort has been spent in developing chemicals for the horticultural industry to retard the growth of woody and herbaceous plants. Recently a group of new growth regulators was introduced which was shown to be effective in controlling the growth of trees without producing noticeable injury symptoms. In this group are MBR 18337 {N - [4-(ethylthio) - 2 - (trifluoromethyl) phenyl] - methane - sulfonamide} (no common name), PP 333 (2RS,3RS) - 1 - (4-chlorophenyl) - 4,4 - dimethyl - 2 - (1,2,4-triazol-1-yl) pentan - 3 - ol (common name paclobutrazol), and EL-500 {α - (1-methylethyl)- α - [4-(trifluromethoxy) phenyl] - 4,4 -dimethyl - 2 - (1,2,4-triazol) - 1 - penten - 3 - ol} (common name flurprimidol). Both EL-500 and PP 333 have been reported to control excessive sprout growth in a number of species when applied as a foliar spray, as a soil drench or by trunk injection (Hare, 1984; Stinchcombe et al, 1984; Webster and Quinlan, 1984; Aron et al, 1985; Sterrett, 1985; Arron, 1985, 1986) MBR 18337 was found to control sprout growth, but at high application rates, plants exhibited phytotoxic symptoms (Sterrett et al, 1983, Arron, 1985). Neither EL-500 nor PP 333, at the various application rates used, have been reported to

cause malformed growth (see e.g. Hare, 1984; Arron, 1985). Trunk injection of growth regulators offers advantages over other application methods such as foliar sprays, soil drenches and soil injection. Drift is avoided, there is greater control over the rate applied, and the exposure of the applicator to the chemical is limited (Domir, 1978; Roberts et al, 1979).

Growth regulators, such as MBR 18337, EL-500 and PP 333, are known to act by inhibiting the biosynthesis of gibberellins (for reviews see - Graebe, 1982; Rademacher and Jung, 1986). While MBR 18337 has been reported to have a mode of action similar to dikegulac, a regulator registered for tree injection in the U.S. (Sterrett et al, 1983), the modes of action of EL-500 and PP 333 have been studied in considerable detail. Both compounds have been shown to interfere with cytochrome P-450, thus blocking the monooxygenases that oxidise ent-kaurene via ent-kaurenol and ent-kaurenal to ent-kaurenoic acid (see - Rademacher and Jung, 1986). These four compounds are intermediates in the gibberellin biosynthesis pathway. The inhibition of shoot growth in plum *(Prunus domestica L)* after the foliar - application of PP 333 observed by Webster and Quinlan (1984) was reversed when the trees were sprayed with a mixture of GA_3 (a gibberellin) and 2,4,5-TP (2,4,5-trichlorophenoxy propionic acid). A similar reversal by GA_3 of the inhibition of shoot growth by PP 333 in apple seedlings *(Malus domestica Borkh)* has been reported (Steffens et al, 1985). The inhibition of shoot or sprout growth in a wide variety of species by PP 333, reported by many workers, is the result of an inhibition of internode elongation (Barrett and Bartuska, 1982; Wample and Culver, 1983; Wood, 1984; Aron et al, 1985; LeCain et al, 1986). Other effects of PP 333 have been observed also, such as an increased tolerance to water stress (Wample and Culver, 1983; Swietlik and Miller, 1983; Wang and Steffens, 1985), a reduction in the number of sprouts formed (Webster and Quinlan, 1984; Aron et al, 1985), a reduction in the size of leaves formed (Wample and Culver, 1983; Wood, 1984; LeCain et al, 1986; Greene, 1986), an increase in chlorophyll content (Wood, 1984) and an increased tolerance to SO_2 (Lee et al, 1985). The increased tolerance to SO_2 induced by PP 333 was reversed by subsequent application of GA_3. There have been reports of increased cold tolerance in crops treated with PP 333 (Dalziel and Lawrence, 1984).

In a recent study (Wang et al, 1986) Steffens and co-workers found that PP 333 inhibited apple sprout extension, and that there was a concomitant change in cell wall composition. Treatment with PP 333 caused an increase in the levels of carbohydrates, rhamnose, arabinose and galacturonic acid, and a decrease in cellulose. Several enzymes could be involved in the

synthesis and metabolism of cell wall carbohydrates in apple sprouts treated with PP 333. PP 333 treatment suppressed wall deposition either by lowering the activities of the required synthetic enzymes or by enhancing hydrolase activity. Changes in cell wall constituents are an important part of plant growth (Cleland, 1971). Sprout growth or elongation is the result of cell elongation rather than cell division (Wilson, 1970). Buds are formed from early summer to early autumn, so that compressed terminal and lateral sprouts all over winter inside the bud scales. The following spring the leaves begin to grow rapidly as the buds swell and "break", and then the cells in the internodes elongate, so that elongation of the sprout occurs (Wilson, 1970).

Sprout length is a function of both the number of internodes and the length of the individual internodes in the sprout. As mentioned above, many workers have reported that the mean internode length in plants treated with PP 333 is less than in control plants. A reduction in the mean number of internodes per sprout would also result in a reduction in the length of sprouts. There have been no reports on the effects of growth regulators on the number of internodes per sprout in woody or non-woody species.

In the present study, the length of sprouts, the length of internodes and the number of internodes per sprout were investigated in silver maple seedlings, growing in the greenhouse, and in silver maple trees, growing at a field site, following treatment with growth regulators. The seedlings were trunk injected with MBR 18337, EL-500 or PP 333 immediately after trimming, while the older trees were injected with the latter two growth regulators after trimming. Trimming trees results in vigorous sprout growth. In apple it has been reported that gibberellin activity in samples from trimmed trees was three times higher than in samples from untrimmed trees (Grochowska et al, 1984) and therefore it is useful to investigate the effects of growth regulators, which are thought to inhibit gibberellin biosynthesis, (see Rademacher and Jung, 1986), in trimmed seedlings and trees. Preliminary data from the present study has been reported previously (Arron, 1985).

2.0 MATERIALS AND METHODS

2.1 Seedlings Grown in the Greenhouse

Two-year-old dormant seedlings of silver maple *(Acer saccharinum L)*, approximately 1.5 m in height, were obtained from the Ontario Ministry of Natural Resources and planted in 37 cm diameter plastic pots in a mixture of shredded topsoil (sandy loam) and peat (1:1). The potted seedlings were placed

in the greenhouse (21°C), watered twice a week, and fertilized every two weeks. Supplemental lighting [110 uEm^{-2}s^{-1} PPFD (400 to 700 nm) (16 h photoperiod)] was supplied. When the seedlings achieved full leaf development 90 specimens were selected on the basis of uniformity of size. At random, nine seedlings were chosen for each treatment.

The stock solutions of the three growth regulators MBR 18337, EL-500 and PP 333 were diluted with methanol to give an appropriate weight of active ingredient in an injection volume of 0.05 ml. Small volumes of methanol have been shown to be non-phytotoxic to trees (Anon, 1984). Three application rates, either in the range recommended by the manufacturer (Anon, 1983, 1984) or similar to those used in earlier studies (Sterrett et al, 1983), were used for each growth regulator. An electric drill with a 2 mm bit was used to drill a 10 mm deep hole, at an angle of 45° from the vertical, in each tree stem between 4 and 5 cm above the soil surface. Any shavings were removed and 0.05 ml of experimental solution introduced. The hole was covered with silicone grease to prevent evaporation and pathogen entry. This application method is similar to that used by Sterrett and co-workers (Sterrett and Creager, 1977), except that the volume of solution introduced was smaller and not under pressure. After application of the growth regulators the seedlings were trimmed to remove approximately one-third of the length of the single major stem and any laterals. A record was made of the location and length of the laterals and the length of the main stem of each seedling. Control seedlings received methanol alone. The seedlings were left in the greenhouse for three months and then the location and length (in cm) of each new lateral or terminal sprout and the number of internodes in each sprout were recorded.

2.2 Trees Grown in the Field

Multi-stemmed 12-year-old silver maple trees growing at Wesleyville GS were trunk injected with methanolic solutions of EL-500 and PP 333 in May of 1985 using a third generation Asplundh tree injector. Injection holes were made with a hand drill fitted with a 5.5 mm (7/32 in) bit. The holes were drilled into the trunk approximately 30 cm from the soil surface, at a slight downward angle (about 5° from horizontal) and at a 30° to 45° angle to the bark surface to intercept the outer sapwood. In every case, injections were made in the trunk below the point(s) where it divided to form two or three major stems. The holes were typically 6 cm in depth and were sealed with silicone grease after injection.

Two different application rates (20 g/L and 4 g/L) were used for each chemical. The volume of solution (and hence the amount of active ingredient) injected into each tree was determined from

the diameter of the tree, using the formula: Volume per tree (mL) = $(dbh)^2$ X 0.492. (Dbh = diameter at breast height) trees with a trunk diameter of 9.5 cm or less had two injection holes while larger trees had three injection holes. Two sets of control trees were included in the experiment. In one set the trees received no injection (control), and in a second set the trees were injected with methanol (methanol control), the carrier in the growth regulator solutions. Ten trees, chosen at random, were used in each of the control and experimental sets. Prior to injection all the trees at the site were trimmed by a forestry crew, with their height being reduced by approximately one-third.

In January 1987, twenty months after the trees were injected, between 6 and 8 limbs were removed at random from the bottom two-thirds of the canopy of each of the ten trees in each experimental and control set. The limbs were returned to the laboratory and the length of all the terminal sprouts and the number of internodes in those sprouts were recorded. Between one and twenty-five terminal sprouts were found on each limb collected. Sprouts which had a length of 1 cm or less were recorded as being 1 cm in length. If anything this would lead to a slight over-estimation of both the length of the average sprout and the average internode length. In two instances one of the ten trees in a set could not be sampled because limb removal would have jeopardized the health of the tree over the long-term.

2.3 Statistical Treatment

For exploratory descriptive data analysis the notch-and-whisker plot procedure in STSC STATGRAPHICS was used. This procedure is a modification of the box-and-whisker plot (McGill *et al*, 1978). A notch added to the box corresponds to the width of a 95 percent confidence interval for the median, and this allows pairwise comparisons at the 95 percent level by examining whether two notches overlap. Overall sprout length and internode length for the sprouts formed above the injection point on the seedlings in the greenhouse and for the terminal sprouts formed on the trees in the field were subjected to the above analysis. As described previously (Arron, 1985) sprouts were found on methanol control seedlings above the injection point only, but in seedlings treated with the three growth regulators sprouts were also found below the injection point. Such growth regulators are thought to move predominantly upwards in the stem, and not downward (Sterrett *et al*, 1983; Sterrett, 1985) and thus sprouts formed below the injection point will have received little if any growth regulator. Sprouting below the injection point has not been reported in older trees.

3.0 RESULTS AND DISCUSSION

3.1 Effects of Trunk Injection of MBR 18337, PP 333 and EL-500 on Sprout Growth in Silver Maple

The effects of trunk injection of the growth regulators MBR 18337, PP 333 and EL-500 on the length of sprouts formed on silver maple seedlings grown in the greenhouse are presented in Figure 1. These sprout growth data have been presented before, but they were not analysed in this manner (Arron, 1985). With the exception of the lowest application rates of MBR 18337 and PP 333, all the treatments resulted in a significant reduction in the growth of the sprouts over the course of the experiment. With both MBR 18337 and PP 333 a dose response was apparent, with higher application rates resulting in greater reductions in growth. With EL-500 all three application rates resulted in a massive reduction in growth. Reductions in sprout growth caused by MBR 18337 (Sterrett *et al*, 1983), EL-500 (Hare, 1984) and PP 333 (Stinchcombe *et al*, 1984; Webster and Quinlan, 1984; Aron *et al*, 1985; Sterrett, 1985) have been reported previously.

The greenhouse study mentioned above was followed by a field study in which single- and multi-stemmed silver maple trees (12-years-old) were trunk injected with PP 333 and EL-500 in May 1985. Reductions in sprout growth were observed in the 1985 (Arron, 1986) and the 1986 growing seasons (Arron, 1987). Limbs were removed from the multi-stemmed silver maple trees in January 1987 and the increase in length of all terminal sprouts in 1986, and the number of internodes in that growth, determined.

The effects of trunk injection of PP 333 or EL-500 (two application rates for each growth regulator - 20 g/L and 4 g/L) into silver maple trees in the field are shown in Figure 2. All four treatments resulted in a significant reduction in the growth of terminal sprouts. While there are a large number of 'outside values' (denoted by a cross in the figure) for each treatment, such observations are not necessarily outliers. In each treatment the number of observations is extremely large, from 343 to 687. The 'outside values' all fall within the range seen in the control and methanol control groups. A lack of uniformity in the inhibition of sprout growth could cause a problem if growth regulators were used under operational conditions. Although trees would still require trimming, the number of sprouts to be trimmed would be much reduced. The results discussed above suggest that the application rate of 4 g/L for both PP 333 and EL-500 results in a drastic reduction in terminal sprout growth, and that the higher application rate of 20 g/L constitutes an overdose for both growth regulators.

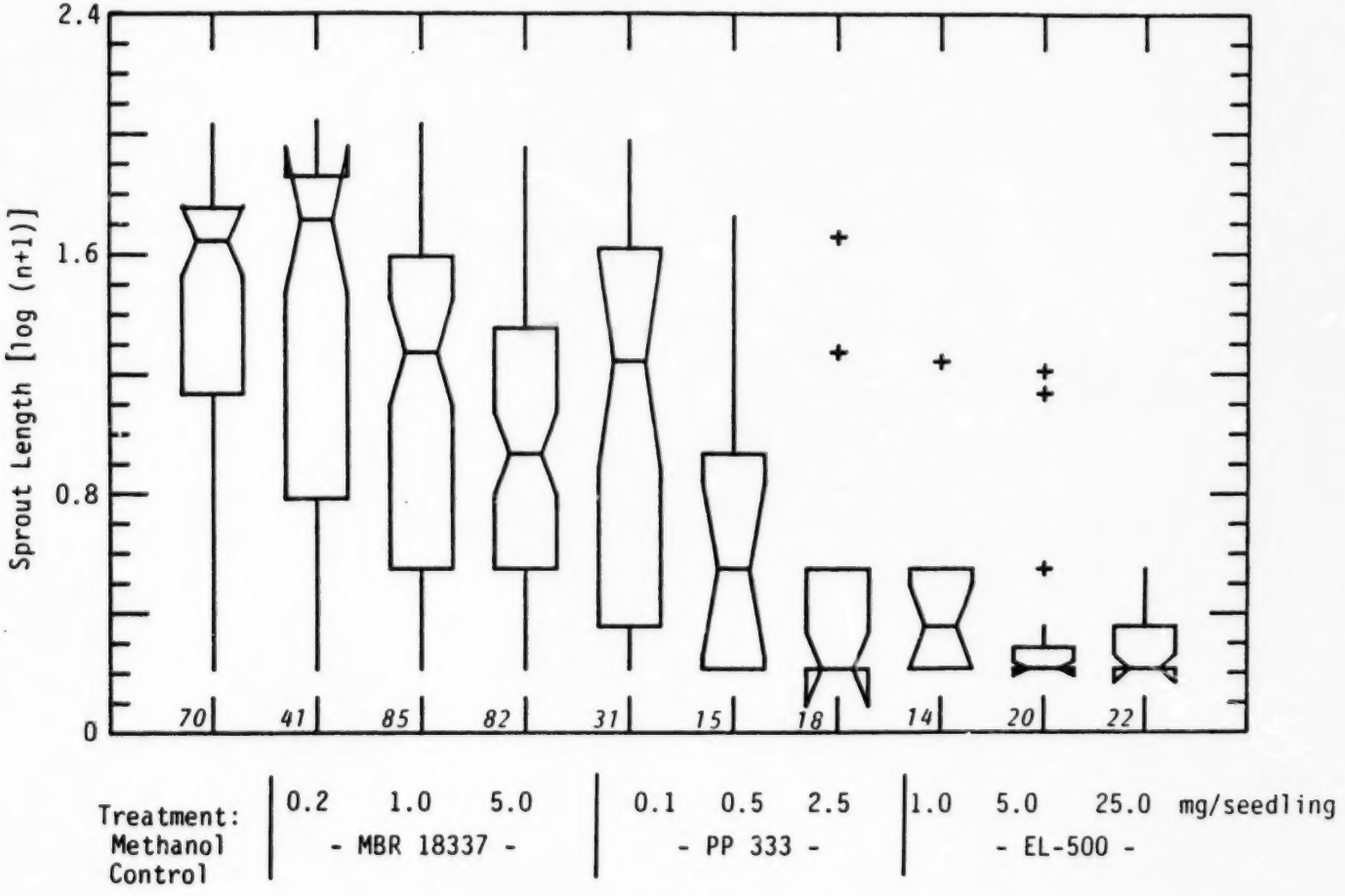

FIGURE 1

EFFECT OF TRUNK INJECTION OF MBR 18337, PP 333 AND EL-500 ON THE LENGTH OF TERMINAL AND LATERAL SPROUTS FORMED ON SILVER MAPLE SEEDLINGS. TRANSFORMED DATA, LOG (n+1), WERE USED IN THE ABOVE ANALYSIS. DETAILS OF THE NOTCH-AND-WHISKER PLOT PROCEDURE ARE GIVEN IN MATERIALS AND METHODS. THE NUMBERS BENEATH EACH BOX REPRESENT THE NUMBER OF SAMPLES IN THAT TREATMENT GROUP.

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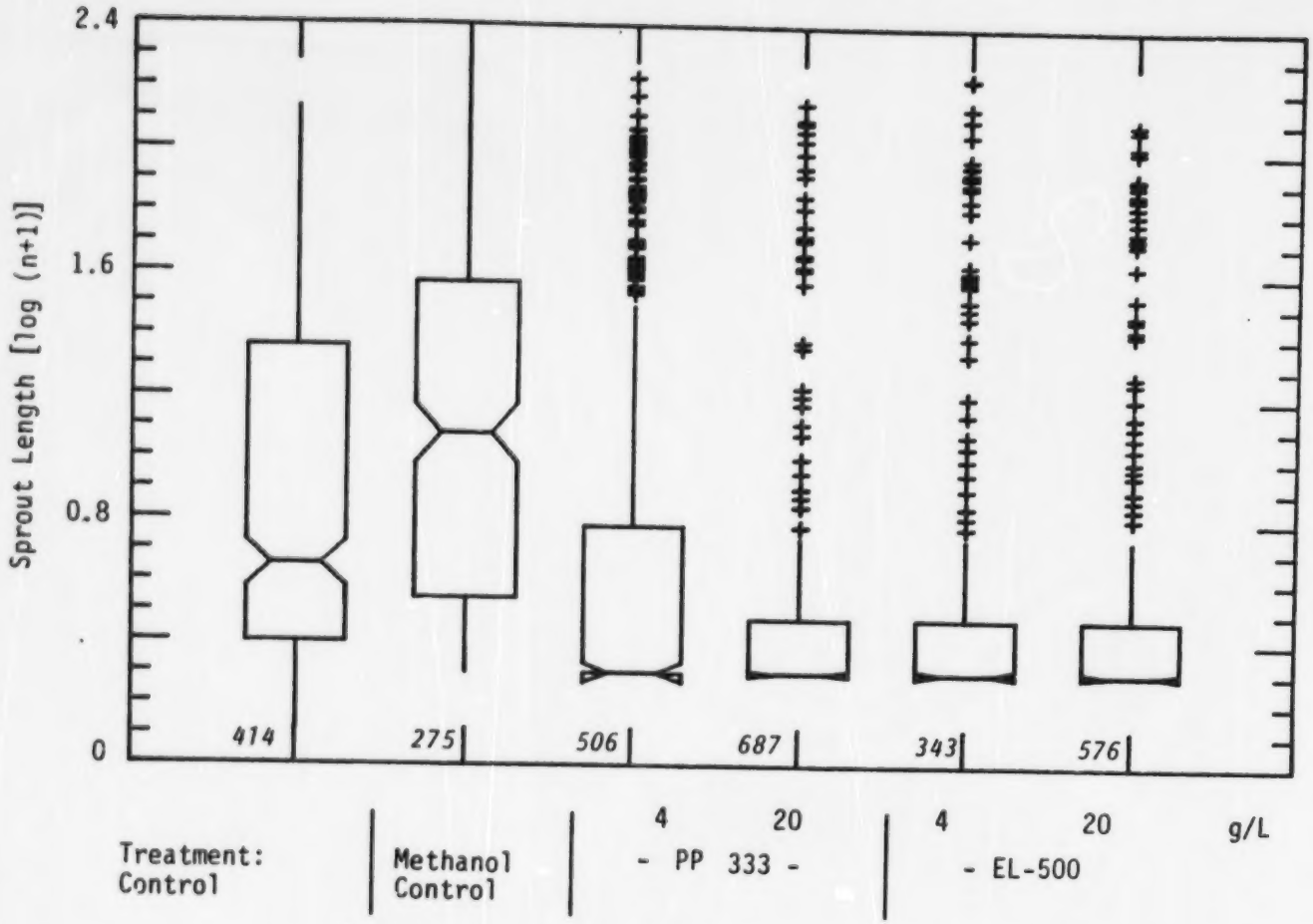


FIGURE 2
EFFECT OF TRUNK INJECTION OF PP 333 AND EL-500 ON THE LENGTH OF TERMINAL SPROUTS FORMED ON SILVER MAPLE TREES AT WESLEYVILLE GS
TRANSFORMED DATA LOG (n+1), WERE USED IN THE ABOVE ANALYSIS

3.2 Effects of Trunk Injection of MBR 18337, PP 333 and EL-500 on Internode Length in Sprouts in Silver Maple

The inhibition of sprout growth described above is the result, in part, of an inhibition of internode elongation. The effects of trunk injection of MBR 18337, PP 333 and EL-500 on the internode length in sprouts formed on silver maple seedlings in the greenhouse are shown in Figure 3. All three application rates of PP 333 and EL-500 resulted in significantly shorter median internode length than in the control. Only the highest application rate of MBR 18337 resulted in a significantly shorter median internode lengths. The data shown in Figure 3 have been presented before (Arron, 1985), although they were not analyzed in this fashion.

A reduction in median internode length was also observed in sprouts formed on field-grown silver maple trees following trunk injection with PP 333 or EL-500 (see Figure 4). Both application rates of PP 333 and EL-500 significantly reduced the median internode length of sprouts formed on multi-stemmed trees. Although it has been reported that PP 333 application results in an inhibition of internode elongation (Barrett and Bartuska, 1982; Wample and Culver, 1983; Wood, 1984; Aron et al, 1985; Steffens et al, 1985; LeCain et al, 1986), many of such studies involved either young plant material, non-woody plants and/or were only conducted over the first growing season after injection of the growth regulator. The results presented in Figure 4 are from 14-year-old trees (12 years at time of injection) and measurements were made at the end of the second growing season after trunk injection.

3.3 Correlation Between The Number of Internodes and Internode Length in Sprouts Formed on Silver Maple Injected With MBR 18337, PP 33 and EL-500

As described above, trunk injection of the growth regulators MBR 18337, PP 333 and EL-500 into silver maple seedlings and trees (PP 333 and EL-500 only) resulted in significant reductions in both sprout growth and internode elongation. Reductions in sprout length can be achieved through a reduction in the length of the individual internodes in the sprout and/or a reduction in the total number of internodes in the sprout. The results for the inhibition of internode elongation by the various growth regulators presented in Figures 3 and 4 were re-analyzed and plotted against the median number of internodes per sprout (see Figures 5 and 6). With both the seedlings (Figure 5) and the trees (Figure 6) both parameters are expressed on a per seedling or tree basis, since the seedling or tree constitutes the statistical unit.

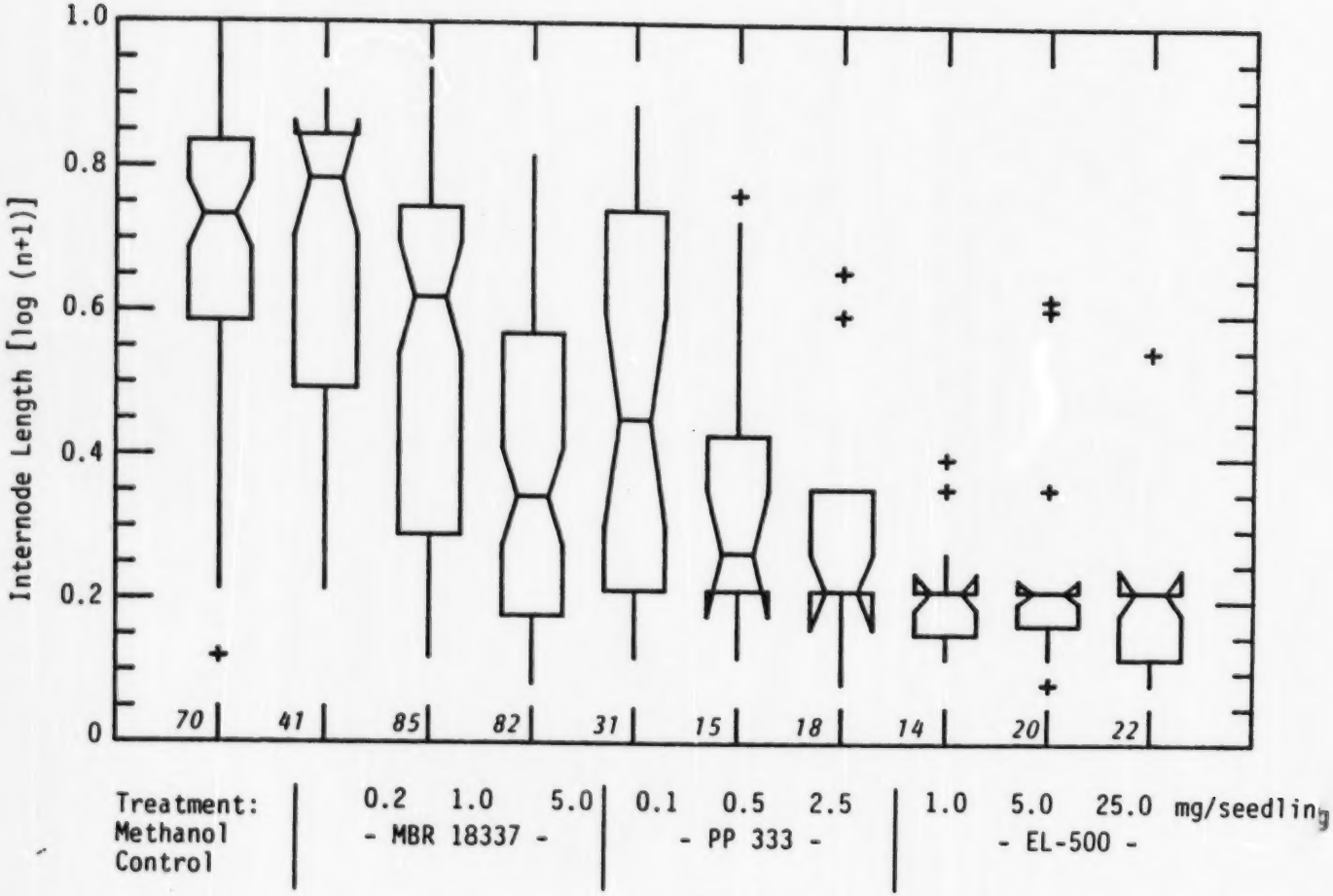


FIGURE 3

EFFECT OF TRUNK INJECTION OF MBR 18337, PP 333 AND EL-500 ON THE INTERNODE LENGTH IN TERMINAL AND LATERAL SPROUTS FORMED ON SILVER MAPLE SEEDLINGS. TRANSFORMED DATA, LOG (n+1), WERE USED IN THE ABOVE ANALYSIS

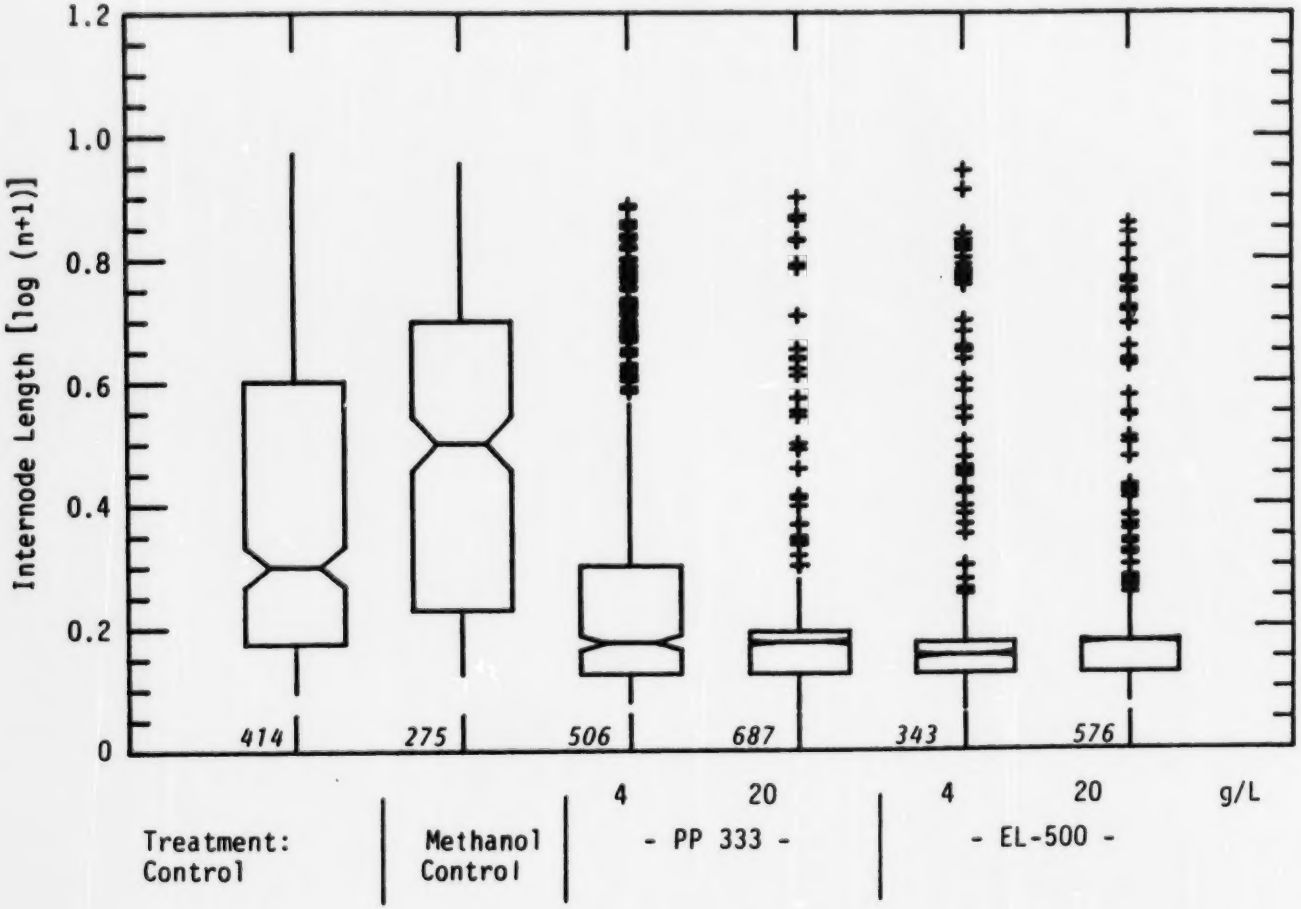


FIGURE 4

EFFECT OF TRUNK INJECTION OF PP 333 AND EL-500 ON THE INTERNODE LENGTH IN TERMINAL SPROUTS FORMED ON SILVER MAPLE TREES AT WESLEYVILLE GS. TRANSFORMED DATA, LOG (n+1), WERE USED IN THE ABOVE ANALYSIS

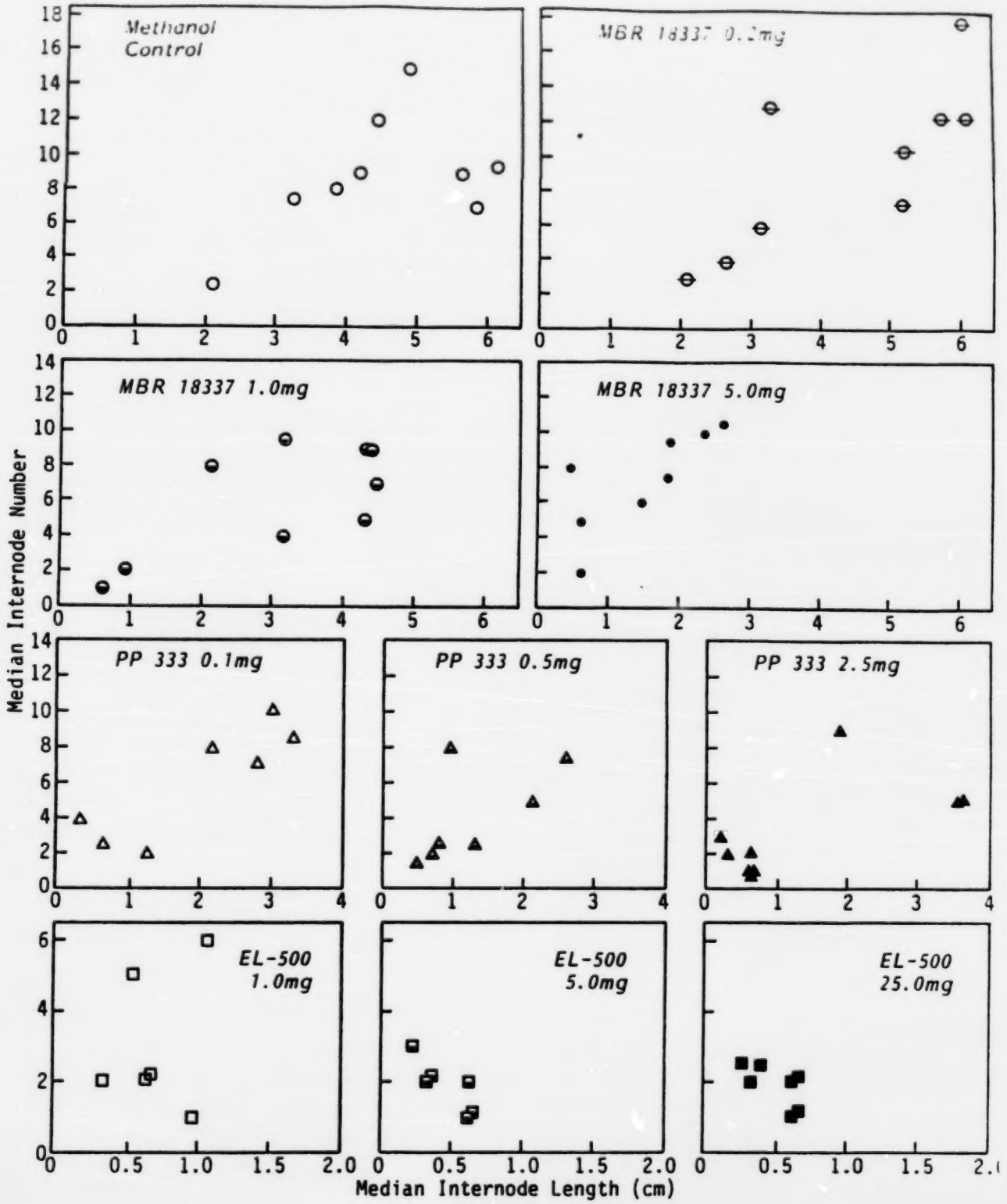


FIGURE 5

PLOT OF MEDIAN INTERNODE LENGTH AND MEDIAN INTERNODE NUMBER FOR SPROUTS FORMED ON EACH SILVER MAPLE SEEDLING INJECTED WITH MBR 18337, PP 333 OR EL-500.

FOR EACH SEEDLING IN THE VARIOUS TREATMENT GROUPS, THE MEDIAN INTERNODE LENGTH AND NUMBER OF INTERNODES PER SPROUT WAS CALCULATED. IN SEVERAL INSTANCES SPROUTS DID NOT FORM ON SEEDLINGS INJECTED WITH DOSES OF EL-500 OR PP 333 AND THEREFORE FEWER POINTS ARE PLOTTED THAN IN E.G. THE CONTROL.

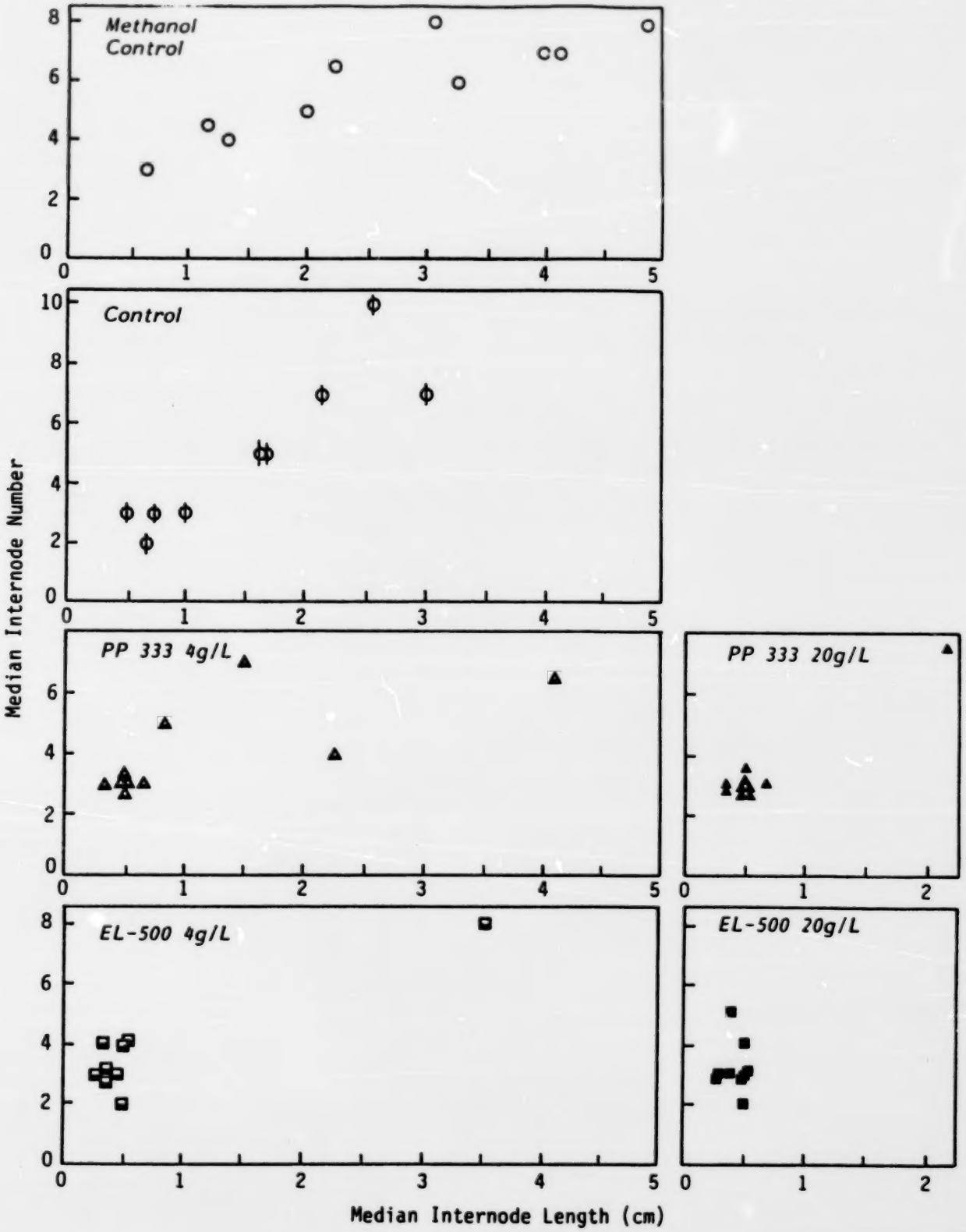


FIGURE 6

PLOT OF MEDIAN INTERNODE LENGTH AND MEDIAN INTERNODE NUMBER FOR SPROUTS FORMED ON EACH SILVER MAPLE TREE INJECTED WITH PP 333 OR EL-500 FOR EACH TREE IN THE VARIOUS TREATMENT GROUPS, THE MEDIAN INTERNODE LENGTH AND NUMBER OF INTERNODES PER SPROUT WAS CALCULATED

In silver maple seedlings grown in the greenhouse, all but one of the seedlings in the methanol control group exhibited a median internode length greater than 3 cm and a median internode number of 7 or greater (Figure 5). The distribution of points in the low application rate of MBR 18337 (0.2 mg per seedling) group was similar to that for the methanol control, although two seedlings exhibited a median internode length of less than 3 cm and three a median internode number of 6 or less. With higher application rates of MBR 18337 median internode lengths were shorter (with 5 mg per seedling all internode lengths were less than 3 cm) but median internode numbers did not appear to decrease. MBR 18337 has been reported to be phytotoxic at high application rates (eg, 5 mg per seedling) (Sterrett et al, 1983; Arron, 1985) while no phytotoxic effects have been reported with either PP 333 or EL-50 (Hare, 1984; Arron, 1985; Sterrett, 1985). With higher application rates of PP 333 and EL-500 it was observed that both median internode length and median internode number were reduced for the majority of seedlings in the experimental groups (Figure 5). With EL-500 for example, the highest application rate (25 mg per seedling) resulted in all seedlings in the group exhibiting median internode lengths of less than 1 cm and median internode numbers of less than 3 (N.B. note different scales for both parameters from rest of figure). Some seedlings had no sprouts with various application rates of PP 333 or EL-500. Trunk injection of both PP 333 and EL-500 into silver maple seedlings led to a decrease in median internode length and a concomitant decrease in median internode number for most if not all the seedlings in the individual treatment groups. Variability of regrowth, in terms of some trees responding better to trunk injection of growth regulators than others, has been discussed previously (EPRI, 1982).

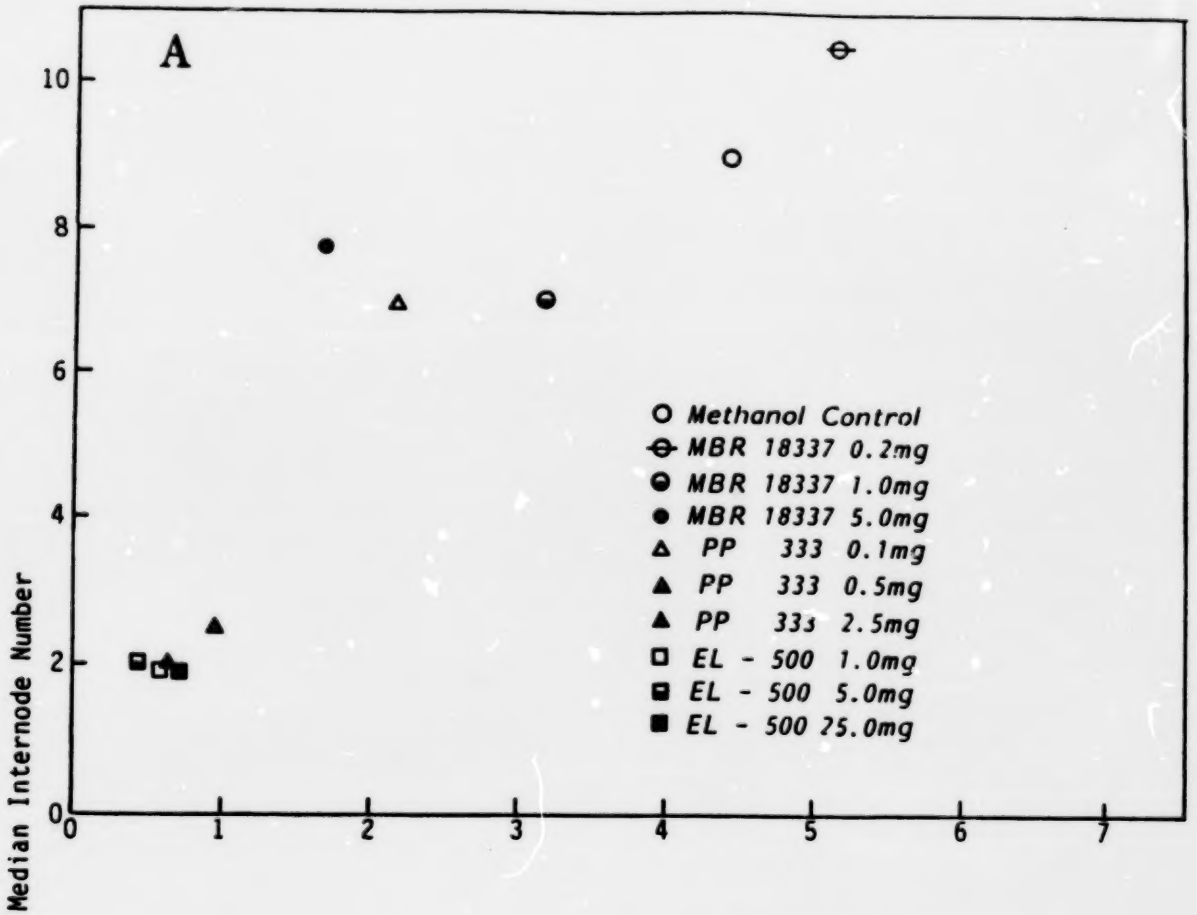
The results of plotting median internode length against median internode number, for each tree in the silver maple field experiment, are given in Figure 6. In the methanol control group, there was great variability between trees, although the points did fall on or close to a line. Median internode length ranged from less than 1 cm to approximately 5 cm while median internode number ranged from 3 to 8. In the control group more trees exhibited a lower internode length and internode number than in the methanol control, although again the points were arranged on or close to a line. The group of trees treated with 20 g/L EL-500 formed a fairly tight cluster, with median internode lengths of 0.5 cm or less and median internode numbers from 2 to 5 with the majority at 3. With the low application rate of EL-500 and the high application rate of PP 333 similar tight clusters were observed, with low median internode lengths and numbers, although with both treatments one tree appeared to be largely unaffected by the treatment. The low application rate of PP 333 resulted in six trees with low median internode

lengths and number, being located in a tight cluster, while four trees had more and longer internodes than those in the cluster.

The results presented in Figures 5 and 6 were re-analyzed, with a median value being calculated from the median values for internode length and number for the seedlings and trees in the various treatment groups. This re-analysis is presented in Figure 7A & B. In the silver maple seedlings (Figure 7A) all three application rates of EL-500 and the two higher rates of PP 333 gave points in a tight cluster with a median internode length of 1 cm or less and a median internode number of three or less. With the exception of the points for the high application rate of MBR 18337 and the low rate of PP 333, the remaining points on the graph were arranged along a line, which appeared to intercept the vertical axis close to one. The minimum number of internodes in a sprout is one. In the field experiment, all four treatment points are arranged in a tight cluster, with a median internode length of approximately 0.5 cm and a median internode number of three. The control and methanol control points represent higher median internode numbers and lengths, although these points and the cluster fall on or close to a straight line. It is difficult to explain the apparent difference between the control and methanol control results. Although methanol is an organic solvent it has not been reported to be phytotoxic in woody plants (Anon, 1984) or to promote plant growth. After injection the methanol is diluted very quickly in the transpiration stream, and little if any is carried up into the growing sprouts.

In the seedling experiments the median internode length in the methanol control was approximately 4.5 cm and that in all the EL-500 and the two higher application rates of PP 333 was from 0.5 to 1.0 cm. Similar results have been reported by Wood (1984) who observed a ten-fold reduction in internode length in spounts on young pecan [*Carya illinoinensis* (Wangenh) K. Koch] seedlings treated with a soil drench of PP 333. This author did not investigate the effects of PP 333 on the number of internodes per sprout.

It is apparent from the results presented in Figure 7 that growth regulators inhibited internode elongation in silver maple seedlings slightly more than in trees (compare Figure 7A with 7B) While this may be the result of the application rates applied, it could be explained in part by the differing growth rates in young and old woody plants, with the rate declining with plant age (Kramer and Kozlowski, 1979). Thus younger woody plants may be more susceptible to inhibition than older plants.



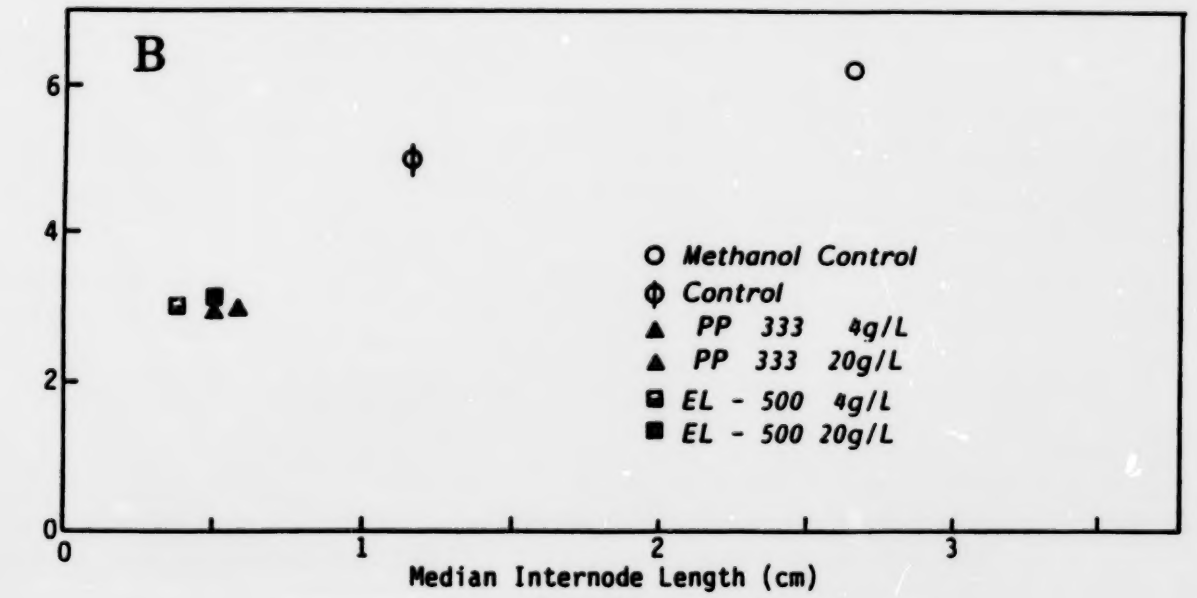


FIGURE 7

PLOT OF MEDIAN INTERNODE LENGTH AND MEDIAN INTERNODE NUMBER FOR A) GROUPS OF SILVER MAPLE SEEDLINGS INJECTED WITH MBR 18337, PP 333 OR EL-500 AND B) GROUPS OF SILVER MAPLE TREES INJECTED WITH PP 333 OR EL-500.
FROM THE MEDIAN VALUES PRESENTED IN FIGURES 5 & 6 A MEDIAN VALUE WAS CALCULATED (MEDIAN OF MEDIANS) FOR EACH TREATMENT GROUP OF SEEDLINGS OR TREES.

The present study has demonstrated that trunk injection of the growth regulators EL-500 and PP 333 results in both an inhibition of internode elongation and a reduction in the number of internodes in sprouts formed on silver maple seedlings and trees. MBR 18337 was used in seedling experiments only, and at the application rates used, internode elongation was inhibited but not internode number. Since the length of sprouts formed in a growing season is a function of both internode length and internode number, growth regulators can reduce sprout growth to a greater extent if both parameters are affected and not simply one.

CONCLUSIONS

1. Trunk injection of silver maple seedlings grown in the greenhouse with MBR 18337 resulted in a significant reduction in sprout growth. A high application rate of MBR 18337 significantly reduced the length of internodes in the sprout, but there was no evidence of the number of internodes per sprout being reduced also.

2. Trunk injection of both silver maple seedlings and trees with EL-500 and PP 333 resulted in significant reductions in the growth of sprouts produced in the first growing season after application (seedlings) or the second growing season (trees). Application of both EL-500 and PP 333 led to a significant reduction in the length of internodes in the sprouts and this was accompanied by a reduction in the number of internodes formed per sprout.

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